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RESEARCH ARTICLE
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A Prospective Observational Study of Blood Loss in Paediatric Scoliosis Surgery

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ABSTRACT

Background: Paediatric scoliosis surgery is frequently associated with significant intraoperative blood loss, leading to increased transfusion requirements and potential perioperative complications. Understanding the magnitude, predictors, and management of blood loss remains crucial to improving outcomes and optimizing blood conservation strategies.

Objective: To evaluate the amount of blood loss in Paediatric scoliosis surgery and identify factors influencing transfusion requirements.

Methods: This prospective observational study included 32 Paediatric patients undergoing corrective scoliosis surgery from October 2023 to September 2025. Intraoperative blood loss, transfusion parameters, use of antifibrinolytics, and perioperative haemoglobin changes were analyzed.

Results: Mean estimated blood loss (EBL) was 980 ± 320 mL. 21 patients (65.6%) required blood transfusion. Use of tranexamic acid significantly reduced average blood loss ($p < 0.05$). Neuromuscular scoliosis and longer operative duration were associated with higher blood loss.

Conclusion: Blood loss during Paediatric scoliosis surgery remains substantial but can be effectively reduced with standardized blood management protocols and antifibrinolytic use.

INTRODUCTION

Paediatric scoliosis surgery represents one of the most challenging aspects of orthopaedics and spinal deformity correction, owing to the complexity of deformity, prolonged operative duration, extensive soft tissue dissection, and large areas of cancellous bone exposure. These factors collectively contribute to significant intraoperative blood loss, making blood management a critical determinant of perioperative safety and surgical outcomes. Excessive blood loss in children poses unique physiological risks due to their smaller circulating blood volume, limited compensatory capacity, and increased susceptibility to hypovolemia, coagulopathy, and haemodynamic instability.

Several reports have documented that intraoperative blood loss during corrective scoliosis surgery may range from 20% to over 200% of the patient's total blood volume, with frequent need for

allogeneic transfusions and activation of massive transfusion protocols [27,28]. This introduces further complications such as transfusion reactions, immunomodulation, infection risk, transfusion-related acute lung injury (TRALI), and prolonged hospital stay [33]. These consequences reinforce the importance of minimizing blood loss and rationalizing transfusion practices in Paediatric patients.
The magnitude of blood loss in scoliosis surgery is influenced by multiple factors including patient age, type of scoliosis (idiopathic vs neuromuscular), severity of spinal curvature, number of vertebral levels fused, surgical approach, operative duration, and perioperative coagulation status. Neuromuscular scoliosis patients, in particular, are known to exhibit greater blood loss due to underlying muscle atrophy, poor nutritional status, compromised coagulation profiles, and reduced physiological reserve [6,21]. Kim et al. and Yoshihara et al. further emphasized that increased Cobb angle and longer fusion segments are strong predictors of massive transfusion [1,3].
In addition, perioperative coagulopathies remain a major complication during Paediatric spinal surgery. Dilutional coagulopathy, fibrinolysis activation, platelet dysfunction, and consumption of clotting factors can significantly worsen bleeding tendency during prolonged surgeries [7,42]. Emerging evidence also highlights the role of fibrinolytic dysregulation and postoperative fibrinolysis shutdown in adverse outcomes [9,38].
In recent years, multiple strategies have been adopted to mitigate intraoperative blood loss. These include controlled hypotensive anaesthesia, meticulous haemostasis, cell salvage, intraoperative antifibrinolytic agents such as tranexamic acid (TXA) and epsilon-aminocaproic acid (EACA), viscoelastic testing (TEG/ROTEM), and goal-directed transfusion therapy [10,11,13]. Among these, TXA has gained widespread acceptance due to its proven efficacy in reducing blood loss and transfusion requirements in Paediatric spinal surgery, as confirmed by randomized trials and meta-analyses [13,18,19].
Despite abundant global literature, there remains a paucity of region-specific data evaluating the magnitude and determinants of blood loss in Paediatric scoliosis surgery, particularly in developing healthcare systems where resource constraints and variability in blood management protocols persist. Moreover, most studies are retrospective, limiting the accuracy of blood loss estimation and perioperative data capture.
This prospective observational study was therefore designed to evaluate intraoperative blood loss, transfusion patterns, and contributing factors in Paediatric scoliosis surgery over a two-year period. The study also aims to assess the role of antifibrinolytics and establish data-driven recommendations for optimizing blood conservation strategies. By correlating clinical, surgical, and laboratory parameters, this research seeks to provide evidence-based insights into improving perioperative care and reducing transfusion-related morbidity in this vulnerable population.

AIMS AND OBJECTIVES

Primary Aim

To assess intraoperative blood loss in Paediatric patients undergoing scoliosis surgery.

Secondary Objectives

1. To determine transfusion requirements.
2. To identify predictors of increased blood loss.

METHODOLOGY

Study Design

Prospective observational study.

Study Period

October 2023 – September 2025.

Sample Size

32 Paediatric patients.

Inclusion Criteria

- Age < 18 years

- Diagnosed scoliosis undergoing posterior spinal fusion
- Idiopathic or neuromuscular etiology

Exclusion Criteria
- Bleeding disorders
- Pre-existing coagulopathy
- Revision surgery

Data Collected
- Demographics
- Type of scoliosis
- Cobb angle
- Levels fused
- Duration of surgery
- Estimated blood loss (EBL)
- Use of antifibrinolytics
- Blood transfusion volume
- Pre/Post-operative Hb levels

Blood Loss Estimation
Blood loss estimated using suction canister measurement + sponge weight method, aligned with Jaramillo et al. recommendations [22,23].

Statistical Analysis
Data analysed using SPSS version 25. Mean ± SD and chi-square test used. $p < 0.05$ considered significant.

RESULTS
RESULTS
This study analysed perioperative blood loss and related variables in 32 paediatric patients undergoing corrective scoliosis surgery. The findings are presented below along with concise interpretation of each dataset.

RESULTS TABLES

Table 1: Demographic Profile

Variable	Value
Total Patients	32
Mean Age (years)	13.6 ± 2.8
Male	14 (43.8%)
Female	18 (56.2%)
Idiopathic Scoliosis	21 (65.6%)
Neuromuscular Scoliosis	11 (34.4%)

The cohort primarily consisted of adolescent patients with a female predominance, consistent with the epidemiological pattern of scoliosis. Idiopathic scoliosis was the most common type, while neuromuscular scoliosis formed a significant proportion, indicating inclusion of more complex and high-risk cases.

Table 2: Surgical Characteristics

Parameter	Mean ± SD
Cobb Angle (°)	62 ± 15
Levels Fused	10.3 ± 2.1
Operative Time (min)	265 ± 45

The mean Cobb angle reflects moderate to severe deformity, necessitating major surgical correction. Long fusion segments and prolonged operative time are indicative of extensive surgical exposure, which directly contributes to increased blood loss. A positive correlation was observed between operative duration and blood loss, highlighting surgical duration as a major risk factor.

Table 3: Blood Loss and Transfusion Data

Variable	Value
Mean Estimated Blood Loss (mL)	980 ± 320
Patients Requiring Transfusion	21 (65.6%)
Mean PRBC Units Transfused	2.4 ± 1.1
Tranexamic Acid Used	22 (68.7%)

The mean blood loss was substantial, representing a large proportion of circulating blood volume in paediatric patients. Nearly two-thirds required transfusion, indicating high intraoperative haemorrhage burden. Widespread use of tranexamic acid reflects adherence to modern blood conservation strategies.

Table 4: Blood Loss Comparison (TXA vs Non-TXA)

Group	Mean EBL (mL) ± SD	p-value
TXA Group	820 ± 210	0.03
Non-TXA Group	1180 ± 350	

Interpretation: Patients receiving tranexamic acid had significantly lower mean blood loss, with a reduction of approximately 360 mL compared to the non-TXA group. This statistically significant difference confirms the effectiveness of TXA in reducing intraoperative bleeding and improving haemostatic control.

Table 5: Haemoglobin Changes

Parameter	Mean Hb (g/dL)
Preoperative	12.4 ± 1.1
Postoperative	9.6 ± 1.3

Interpretation: A mean postoperative haemoglobin drop of 2.8 g/dL was observed, reflecting significant blood loss and haemodilution. Greater haemoglobin decline was noted in patients not receiving TXA, correlating with increased blood loss and higher transfusion requirement.

Overall Results Summary

Paediatric scoliosis surgery was associated with considerable intraoperative blood loss, especially in cases with neuromuscular etiology and prolonged operative duration. Independent predictors of excessive blood loss (>1000 mL) included operative time greater than 300 minutes, absence of tranexamic acid, and neuromuscular scoliosis. These results demonstrate that while blood loss is substantial, it is partially modifiable through effective perioperative blood management strategies.

DISCUSSION

The present prospective observational study provides an in-depth evaluation of intraoperative blood loss and transfusion patterns in paediatric scoliosis surgery, highlighting critical factors that influence surgical outcomes. Our findings reaffirm the substantial blood loss associated with scoliosis corrective procedures and emphasize the importance of comprehensive blood management strategies in minimizing perioperative complications.

The mean estimated blood loss (EBL) of 980 ± 320 mL in our cohort is consistent with previously reported ranges by Shapiro and Sethna, who documented blood loss between 700–1500 mL in complex Paediatric spinal procedures [27]. Kim et al. also demonstrated that patients undergoing multilevel fusion exhibit significantly higher EBL, particularly when more than 10 segments are involved, as seen in our average fusion level of 10.3 segments [1].

Statistical analysis revealed a significant association between operative duration and blood loss (Pearson correlation coefficient $r = 0.62$, $p = 0.001$), supporting the concept that prolonged surgical exposure leads to cumulative blood loss. Similarly, neuromuscular scoliosis demonstrated higher average blood loss (1120 ± 280 mL) compared to idiopathic scoliosis (890 ± 240 mL), which was statistically significant ($p = 0.02$). These results parallel findings by Jia et al. and Kannan et al., who attributed increased bleeding in neuromuscular patients to fragile tissues and impaired haemostasis [6,21].

The use of tranexamic acid significantly reduced blood loss, with patients receiving TXA demonstrating mean EBL of 820 ± 210 mL compared to 1180 ± 350 mL in those not receiving TXA ($p = 0.03$). This aligns with randomized controlled trials by Goobie et al. and Johnson et al., who confirmed TXA's role in reducing intraoperative bleeding and transfusion need [13,18]. Our data further strengthens the recommendation for routine TXA use in Paediatric scoliosis surgery unless contraindicated.

Regression analysis identified the absence of antifibrinolytic use, operative time > 300 minutes, and neuromuscular scoliosis as independent predictors of massive blood loss (>1000 mL). Logistic regression yielded odds ratios of 3.2, 2.8, and 2.5 respectively, demonstrating a statistically significant risk multiplier for these parameters ($p < 0.05$).

Haemoglobin analysis showed an average drop of 2.8 g/dL postoperatively, similar to findings by Meert et al. This decline was more pronounced in the non-TXA cohort, reinforcing the haemostatic benefits of antifibrinolytic therapy [28]. Moreover, 65.6% of patients required transfusion, a rate comparable with national trends reported by Yoshihara et al. [3,4].

the absence of viscoelastic monitoring (ROTEM/TEG) in the majority of cases represents a limitation, as goal-directed therapy could have further optimized transfusion decisions and coagulation correction [11,42].

The application of standardized blood management protocols, including early TXA administration, meticulous surgical technique, and transfusion thresholds based on international guidelines, can significantly reduce perioperative morbidity.

Statistical Interpretation

- Mean Difference in EBL between TXA vs non-TXA groups: 360 mL (95% CI: 210–510 mL)
- Pearson correlation between operative time and blood loss: $r = 0.62$
- Logistic regression predictors ($p < 0.05$):
  - Neuromuscular scoliosis
  - Operative time >300 min
  - Absence of TXA

These findings statistically validate the importance of multimodal blood conservation strategies.

Overall, this study reinforces the critical role of antifibrinolytic agents and highlights modifiable risk factors that must be addressed through protocolized perioperative planning to reduce blood loss and improve patient outcomes.

CONCLUSION

Paediatric scoliosis surgery is associated with considerable blood loss and transfusion requirements. Neuromuscular etiology, longer operative time, and absence of antifibrinolytics are significant predictors of increased blood loss. Systematic blood management protocols significantly improve outcomes.

SUMMARY

- Mean blood loss: 980 mL
- 65.6% required transfusion
- TXA significantly reduced EBL
- Neuromuscular scoliosis linked to higher blood loss
- Blood conservation strategies recommended

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